Melbourne's terrestrial invertebrate biodiversity: losses, gains and the new perspective

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Abstract

The most diverse group of animals in the greater Melbourne region is the invertebrates. They are essential in maintaining many ecological functions in the varied environments across the area. Yet we lack basic information on the identity, distribution and biology for most species. Historical information and collections are important in understanding the fauna of Melbourne, but the environment is always changing and the different species of invertebrates can adapt to these changes. This has resulted in a Melbourne invertebrate fauna comprising native species that have always resided in the region, and invertebrates that have been introduced since European settlement either from overseas or from other parts of Australia. Despite the lack of information about the fauna at the time of European settlement, invertebrates are still a rich resource for studying and understanding the nature of Melbourne. (*The Victorian Naturalist* **128** (5) 2011, 201–208)

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In the 1900 *Handbook of Melbourne*, Charles French provided a very general summary on the insect life with an emphasis on beetles, moths and butterflies, phasmids, mantids, cockroaches, dragonflies, termites, thrips, wasps, ants, bugs and houseflies. French (1900a) titled his chapter *Victorian Entomology* and highlighted available information. He named fewer than 20 species of insects, but provided information on the genera that were found. There was an emphasis on beetles, and French (1900a) estimated that there were 450 species of jewel beetles (buprestids) and weevils (curculionids). Interestingly, French listed two exotic insect species: the Oriental cockroach *Blatta orientalis*, which incidentally may be African in origin, and the Pear Slug *Caliroa cerasi*, which is a sawfly from the USA. French (1900a) made two important comments about the insects. First, he decried the lack of a national collection to house Australian insects, and secondly, he stated that a lot of material was sent overseas. At that time, the entomology collection at the National Museum of Victoria was small and without an entomological curator, and French himself was establishing a small collection of agricultural insect pests (which he later described in his five volume series *Destructive Insects of Victoria*) (French 1891–1911).

The critical first step to understanding the importance of terrestrial invertebrate biodiversity in the Melbourne region is simply knowing what the fauna comprises. There are two important questions: (1) What was the fauna before European settlement altered the environment and (2) how will the fauna change in the face of increasing environmental change? The lack of any 'baseline' inventories of terrestrial invertebrates in Melbourne, the diversity of habitat types across the region, and the fact that these habitats were not altered in a consistent manner, resulted in some habitats with virtually no good quality remnants and others with good representative remnants. Some of the environments within the region have undergone enormous change since European settlement; they have been grazed, cleared for agriculture, used for industrial development and for buildings (homes and offices), and some of these altered areas have even been restored for conservation of native biota.

The definition of Melbourne in this paper is the greater Melbourne region, including areas surrounding Port Phillip Bay, the Dandenong Ranges, and the new urban growth corridors that extend east, north and west. It includes urban (city), suburban and rural environments (including conservation reserves of different types within all these environments). Industrialised countries are characterised by up to 80% of their populations residing within cities (Magura *et al.* 2008a) and Australia is no exception to this, with Melbourne being a good example.

There is a tacit assumption that urbanisation results in habitat destruction and biodiversity losses. This is a fairly simplistic view because it does not take into account the degree of change caused by urbanisation, the large amount of spatial and temporal variation in urban environments, as well as factors that may actually enhance native biodiversity.

This paper reviews our knowledge of the biodiversity of terrestrial invertebrates in the greater Melbourne region, and assesses the different environmental factors that determine the composition and long-term survival of the fauna.

Terrestrial invertebrates of the greater Melbourne region

Background information

Information on invertebrates based on traditional owner knowledge is very rare. The use of insects (and other invertebrates) was probably very important for local Aborigines, and the clan that lived in the Yarra Valley area (Wurrundjeri), is named after the edible grub (jeri) that lives in the white or Manna Gum *Eucalyptus viminalis* (wurrun) (Crawford 2008).

Possibly the largest collection of insects was made by the English actor and collector Henry Edwards in the 1850s (Brown-May and May 1997). He collected and identified approximately 2000 species of insects. This collection was purchased by Frederick McCoy to start the entomology collection of the new National Museum of Victoria. Although Edwards did publish information on his later observations on the life histories of Lepidoptera, he did not write about his Melbourne insect collection except in a letter to Mr John Jones in Worcester in 1854 (Edwards 1854). Frederick McCoy (1878-1890) illustrated and described 26 species of insects in his *Prodromus of the Zoology of Victoria.* French (1900a) provided a brief introduction to Victorian insects, but his main contribution is his five volume *Destructive Insects of Victoria* (French 1891-1911) in which he illustrated and discussed 110 species of plant pest insects and mites.

Members of the Field Naturalists Club of Victoria also contributed to documentation of invertebrates from Melbourne. Hall and Thiess (1979) list articles on terrestrial invertebrates in *The Victorian Naturalist* from the following suburbs (and include the year of publication): Belgrave (1909), Blackburn (1947), Clayton (1894), Croydon (1914), Dandenong Ranges (1923), Ferntree Gully (1890, 1892), Diamond Creek (1928), Hurstbridge (1926), Kinglake (1931), Macclesfield (1949), Melbourne (1919), Mooroolbark (1933), Mt Evelyn (1922), Oakleigh (1890), Plenty (1892, 1899), Ringwood (1890, 1922), South Morang (1929), Springvale (1894), Upper Ferntree Gully (1906), Upwey (1923), Wandin (1928), Wandong (1903), Warrandyte (1894), Wonga Park (1928), and Yan Yean (1926). One member took his study of urban natural history seriously by collecting insects in a 3rd floor office in Collins St over six months (Searle 1919); most were species normally associated with human dwellings.

What do we know about the terrestrial invertebrates of Melbourne?

The information on the terrestrial invertebrate fauna of Melbourne is fragmented. Unlike groups such as vascular plants and all the vertebrate groups, we do not know the number of species, their distributions, and we lack data on changes in species composition, distribution and abundances for terrestrial invertebrates. This is primarily due to the treatment of invertebrates either as pests or simply as not important. Conservation agencies have not taken on the management of terrestrial invertebrates unless they are listed as a species of conservation significance, and despite their acknowledged essential roles in providing ecosystem services, no strategy has ever been developed to attempt to document or understand most of our faunal biodiversity.

However, we do know that Melbourne's terrestrial invertebrate biodiversity is very rich. We do have a lot of collections and records that have not been thoroughly used, and the level of information on each group of invertebrates varies considerably. Some, such as butterflies and dragonflies, are relatively well known in that most species have been described and there is information on their biologies and distributions (although we could probably do with more information on many of them). In contrast, there are invertebrate groups with undescribed species and little or no information on their biologies.

Factors that influence terrestrial invertebrate biodiversity

The European settlement of Melbourne saw habitat destruction or simplification, habitat fragmentation, creation of new barriers to natural dispersal, altered environmental conditions (hydrological, climatic), and creation of new habitats (buildings, transport infrastructure, exotic parks and gardens and non-endemic native parks and gardens). Amongst this, some good quality remnant native vegetation survived. One important factor is the broad spatial scale that some of these changes covered through establishment of agriculture, large scale industrial development and large scale urban expansion. In addition, there is the whole issue of the introduction of exotic plants and animals.

The current terrestrial invertebrate fauna is a composite of native species that have survived since European settlement and native and exotic species that have been introduced since European settlement. There is a tendency to use species richness (number of species) as an indicator of biodiversity with the assumption that higher species richness is better. No doubt some native species have been lost (either locally extinct or even possibly totally extinct) within the Melbourne region (and remember that extinction is part of evolution), but it is possible that a highly altered Melbourne environment may have more invertebrate species than at the time of European settlement. The composition is dependent upon suitable habitat, suitable food and biotic interactions (biotic competition, natural enemies) that allows long-term survival of the species. The question is whether the conditions are suitable for the species that we want to survive.

Habitat destruction or simplification can be at the very local level (e.g. loss of particular host plant species, leaf litter, soil and large old trees) or whole communities (e.g. western basalt plains native grasslands). This can lead to loss of native species and the ecosystem services that they perform. For example, a loss of a particular plant species means that its host specific herbivores have no food. Loss of host plant specific pollinators means that there is no natural mechanism for pollination. Biotic interactions can change, and some native insects may be able to survive by switching to another plant species. Some native plants may be pollinated by exotic honey bees and some native pollinators may pollinate exotic plants. However, many changes are more subtle and take a longer time for adverse effects to become apparent. For example, fragmentation may result in smaller habitat areas, but the viability of these smaller areas for invertebrates can be affected by edge effects, greater ease of invasion by exotic invertebrate species, reduced ability to disperse (barriers), and genetic bottlenecks. As insect development is temperature-dependent, and edge effects are associated with slightly higher temperatures, this may result in increased population numbers. Furthermore, larger cities generally have higher ambient temperatures (heat island effect), so insect numbers can sometimes be higher in these areas.

Effects of urbanisation on insects

There has been a lot of research on the effects of urbanisation on invertebrates overseas. The assumption in some of these studies is that increased urbanisation leads to loss of species. Urban growth and industrial expansion led to species losses in Britain for example, but with the exception of the most highly disturbed areas, natural recolonisation occurs to establish a new equilibrium (Davis 1976). Urban environments can support rich insect faunas (Frankie and Ehler 1978; Connor *et al.* 2002; McKinney 2008), although the abundances of many insect species can be reduced and local extinctions can occur (Connor *et al.* 2002). The adverse effects may take a much longer time; in Italy, historical records indicate that increasing urbanisation has seen a marked impoverishment of insects associated with greater urbanisation (Zapparoli 1997; Brandmayr *et al.* 2009). Most studies found a change in the composition of the fauna. This can involve changes in the ratio of opportunistic and specialist species in the case of ground beetles, ants, spiders and isopods (Grandchamp *et al.* 2000; Magura *et al.* 2004; Lessard and Buddle 2005; Magura *et al.* 2008a,b, 2010), just to cite a few of the numerous overseas studies.

There have been considerably fewer studies on the effects of urbanisation on Australian invertebrates. These studies have involved comparisons of small urban remnants and larger patches of the same vegetation type (Christie and Hochuli 2009) or the invertebrate fauna of a single tree species (*Angophora costata*) in urban or large continuous areas of the same vegetation type (Christie *et al.* 2010). Christie and Hochuli (2009) found no differences in the number of species of wasps in urban and larger patches, but different trophic structures of arboreal invertebrates in the centre of larger patches compared to the edges of large patches and in small urban remnants. Edge effects are also very important. Gibb and Hochuli (2002) found that the small and large fragments of similar remnant vegetation in urban environments supported different invertebrate assemblages.

New 'habitat' factors

The Australian studies listed above involve plant-dependent insects. Urban areas are characterised by many non-living habitats such as buildings (homes, offices, factories) which can provide habitats for invertebrates (walls, cavities, timber, stones) and roads (which can be a barrier to dispersal on one hand, and a corridor for dispersal on the other). Unregulated industries can be a source of pollution that could kill some invertebrates. Most urban areas have parks and gardens; the plants may be native or exotic, and this can affect host plant relationships (native insects adapting to exotic plant species or exotic insects adapting to native plant species). Exotic weeds may exclude native plants and thereby deprive some native insects of their food and habitat. The effects of roads (one of the main infrastructure elements in urban environments) on invertebrates can be very important. Roads can act as a barrier to dispersal for ground active species (Yamada *et al.* 2010), but may also be a cause of invertebrate road deaths.

Artificial night lighting

One of the characteristics of cities that is often overlooked as an ecological factor is artificial night lighting. Moonlight has a significant role in influencing insect activity and dispersal, and artificial night lighting may have a significant effect on insects by disrupting normal insect activity by attracting them to lights. Eisenbeis (2006) estimated that high pressure mercury lamps in a German town with 20 000 street lights will attract and kill about 3 million insects per night or 360 million during the warmer months of June to September. Frank (1988) reviewed the effects of outdoor lighting on moths and found that it disturbs flight, vision, navigation, migrations, dispersal, oviposition, mating, feeding, circadian rhythms, photoperiodism and crypsis in some moth species. It exposes moths to increased predation. While Frank (1988) recorded no extinctions of moths due to outdoor lighting, the effect on population dynamics of some species may be marked, especially if they are populations already reduced by habitat loss and fragmentation (Frank 2006). On the other hand, the insects attracted to night lighting may provide an important source of food for nocturnal insectivores such as bats (Scanlon and Petit 2008). One of the important insect migrations in eastern Australia is that of Bogong moths *Agrotis infusa* between their feeding sites in the lowlands and their over-summer sites in the alps (Common 1954). Bogong Moths are an essential food item for the threatened Mountain Pygmy Possum *Buramys parvus*, and the moth populations may be getting smaller because of agricultural insecticide application to reduce larval numbers, reduced over-summer habitats in the alps because of climate change, and loss of flying adults attracted to night lights.

Exotic invertebrates

Another threat to native invertebrate biodiversity is the introduction of exotic invertebrates. The number of introduced exotic invertebrate species in Victoria is difficult to determine. Some were introduced for food production or to increase soil fertility, such as the European honeybee *Apis mellifera* L. and several species of earthworms; others for biological control of plant pests or weeds; and many have been introduced accidentally. The issues associated with the European honeybee and the Bumblebee *Bombus terrestris* L. (currently in Tasmania) are outlined in greater detail in Collett *et al.* (2007) and Hingston (2007). Exotic invertebrates that are considered a danger to the native fauna include the Argentine ant *Linepithema humile*

(Mayr), the Big-headed ant *Pheidole megacephela* (Fabricius), the European wasp *Vespula germanica* (F.), Portuguese millipedes *Ommatoiulus moreletii* (Lucas), and several species of slugs and snails (Heterick *et al.* 2000; Collett *et al.* 2007; Callan and Majer 2009). The impacts of these species have not, in most cases, been determined. The exception is the detrimental effects of Argentine ants on native ants (Rowles and O'Dowd 2009). The European wasp is an example of a species whose ecological impacts are not known. While the control of European Wasps has been driven by their impact on humans (their venom and also the way they impact on social gatherings), there are anecdotal observations on the predation of many native insects by European wasps. One suggestion, at this stage unsubstantiated, is that the decline of Emperor gum moths *Antheraea eucalypti* Scott in urban Melbourne is due to predation by European wasps.

The new perspective

Every major city is different, and ultimately we would expect Melbourne to have its own unique invertebrate fauna whose composition is determined by the remnants of the original environments, exotic introductions, new anthropogenic habitats, and efforts to reintroduce 'native' habitats.

The remnants include the western basalt plains grasslands, the coastal vegetation, especially of the peninsulas surrounding Port Phillip Bay, and the eucalypt woodlands and forests to the north and east. Some of these environments, especially the eucalypt woodlands and forests, may be in large enough remnants to retain much of the original invertebrate faunas, although they do face threats from invasive species (both plants and animals), and more recently, from fuel reduction burns whose long-term effects on large elements of the invertebrate fauna and their functions are largely unknown. The western basalt plains grasslands are in a more precarious state because of the widespread loss and fragmentation they have suffered; information on the invertebrates of these grasslands is still lacking (Yen and Kobelt 2009). In the non remnant environments, there are features that did not exist before European settlement, such as buildings and roads. In some cases, the built environment may have habitats analogous to native habitats (Lundholm and Richardson 2010), and some native invertebrates are able to adapt: spiders are a good example of a group where some species have adapted. An example of the use of man-made structures by spiders is the immense concentration of orb-weaving spiders recorded in a roofed four acre waste treatment plant in Baltimore (USA) that had 11 species of spiders and over 31 000 individuals (about three quarters of which were young hatchlings) (Greene *et al.* 2010). However, some elements of native habitats, such as large old trees, are in decline and it will take a long time for them to be replaced. Another element that is often removed for aesthetic or fire threat purposes is large coarse woody debris. The built environment has many elements that can be used by native invertebrates: gardens, parks, rail and road reserves, streetscapes, stream banks and drainage channels; in all these examples, the plants can be native and/or exotic species.

Urban environments contain an eclectic mixture of different types of habitats, and often there are more resources available and the number of invertebrate species residing in urban locations may in fact be greater than the number in native environments. No doubt some of these species are exotic species or native species that have been accidentally translocated with native plants from other parts of Australia.

Habitat restoration or creation

Besides conservation of remnants, there is the option of habitat restoration, or in some cases, habitat creation. The former applies to degraded remnants, while the latter applies to situations where the original habitat is totally changed and an attempt is made to recreate that habitat (including corridors to link remnants). In most cases, there is an emphasis on recreating pre-European settlement habitats based on vegetation and drainage patterns. The question of invertebrates usually is not asked, and often only involves planting known food plants, especially of butterflies, in the hope that they will be recolonised. Habitat recreation may not be successful if limits to dispersal prevent colonisation (Lundholm and Richardson 2010). Further, no consideration is ever given to invertebrates associated with decomposition or pollination in these situations. Even if we can recreate a 'native' habitat based on plant species composition and structure, there is no guarantee that the conditions are suitable for the native invertebrate fauna that we are trying to maintain. Habitat restoration or creation is often a complex process, and another factor that is relevant for invertebrates is, how do we manage for ecological succession? This is especially pertinent for habitats that rely on floods or fire as part of their successional processes.

Climate change

In some ways, the climate associated with large cities provides an insight into possible longer-term climate change issues. Cities generally have higher temperatures (the heat island effect) and higher levels of carbon dioxide from vehicles and industries. The city climate may be more moderated. Higher temperatures can increase the rate of invertebrate development, and the moderated climate (such as less severe frosts) may see increased populations of many invertebrates. This could be a problem with plant pest species. However, the effects of climate change could be even more severe if we consider the way it could change flowering and leafing phenology. A review of flowering phenology in urban environments suggests that spring-blooming plants in a variety of ecosystems in North America, Europe, and China tend to bloom earlier in the city than in the surrounding un-urbanised habitat. Moreover, ephemerals, early spring bloomers and insect-pollinated plants in these environments tend to be more sensitive than perennials, mid- or late-spring bloomers and wind-pollinated plants (Neil and Wu 2006). We lack information on how these changes could affect plant feeding insects, insect pollinators and the remainder of the food chain (natural enemies such as predatory invertebrates, parasitoids, birds, lizards and mammals).

Lepidoptera as an example

The group of insects that we have most knowledge about in the greater Melbourne region is the butterflies. Approximately 75 species of butterflies are found in the greater Melbourne region; only one species, the Cabbage White Butterfly *Pieris rapae* L., has been introduced from overseas. Many species have declined because of habitat loss, and some are listed as threatened. Most urbanisation in Australia is on the coast, and increasing intensive recreational activity coupled with increasing urbanisation threatens many butterfly species, with exotic weeds and inappropriate fire regimes as major threats in remnant bushlands. Some species adapt to modified habitats and some species can use exotic plant species (New and Sands 2002).

While species, such as the Small ant blue butterfly *Acrodipsas myrmecophila* (Waterhouse and Lyell) that may be naturally rare have gone from the region (White 2003), others have lost so much habitat that they are classed as 'conservation dependent' because their continued existence within the Melbourne region depends upon human management of their remnant habitats. The best example is the Eltham copper butterfly *Paralucia pyrodiscus lucida* Crosby. This species is part of a complex tritrophic relationship that involves an appropriate food source (*Bursaria spinosa* Cav.) and an attendant ant (*Notoncus* sp.) which tends the larvae. However, appropriate conditions for survival of the Eltham copper butterfly depend upon appropriate understorey vegetation (fire dependent) (Canzano *et al.* 2007; New 2010). The survival of the Eltham copper butterfly within Greater Melbourne depends upon managing the small remnant patches on which it is currently known and trying to establish more adjacent habitat.

Another lepidopteran of conservation concern is the Golden sun moth *Synemon plana* Walker, a species closely associated with temperate native grasslands in south-eastern Australia (New *et al.* 2007). This is a difficult species to study because its larvae have a long period underground feeding on plant roots, and adults emerge and live for a short period. It was considered a very rare species known from a small number of locations, but after more intensive survey effort, it is now known from more locations (Gilmore *et al.* 2008). This species presents us with a real dilemma: is it really in decline, or is it very difficult to survey, or has there actually been an increase in numbers over recent years? The Golden sun moth is posing a real conservation issue because it is found in the urban growth corridors to the north and west of Melbourne. To complicate matters further, there are indications that its larvae may be able to feed on the exotic weed Chilean Needle grass *Nassella neesiana* (Trin. & Rupr.) Barkworth (Braby and Dunford 2006).

It must be remembered that butterflies are the best known group of our insects, and even with butterflies there are large knowledge gaps on the biology and distribution of many species. The state of knowledge with most other invertebrate groups is even worse.

The future

As we do not have detailed lists of native species that occur in the greater Melbourne region (nor do we have the expertise to identify many of the invertebrate groups if we are able to collect more specimens or even examine existing collections), the options to consider in conserving Melbourne's invertebrate biodiversity appear simple:

- Conserve as large as possible patches of remnant habitats
- Establish corridors for natural dispersal between remnant patches
- Establish suitable invertebrate microhabitats
- Plant endemic native species
- Control current exotic pest invertebrates
- Prevent incursions by exotic species (plants and animals) both from overseas and from other parts of Australia.

While these may be simple guidelines in principle, they are enormous undertakings that will require large amounts of resources.

These guidelines will be influenced by the location within the Melbourne region because the degree of human disturbance and the amount of large-scale remnant habitat varies across Melbourne. No doubt the larger areas of good remnants are found in Melbourne's east, where woodlands and forests have been retained in water catchments and conservation reserves. While urban encroachment to the southeast, north and west of Melbourne has involved urban growth corridors, urban development in the east has probably had more of a conservation theme than in the larger growth corridors. Consequently, the large urban corridors have encroached into the native grasslands and grassy woodlands. As the areas to the north, west and southeast of Melbourne were converted for agricultural use at an earlier stage in Melbourne's history through wide scale vegetation clearing, they would have a smaller pool of native invertebrates for recolonisation, and harbour more exotic plants and invertebrates. The coastal regions are also under increased pressures by development for recreation, so their situation is similar to that of the larger urban growth corridors.

We know that invertebrate biodiversity will be high within the greater Melbourne region. The question is whether we have the native species required to maintain essential ecosystem functions such as pollination, decomposition, control of pests, etc. Consequently we cannot leave the invertebrates as a 'black box' and hope that it functions properly. We do need to learn more about the fauna and it is not too late to start to study the invertebrates of greater Melbourne in more detail. Remnant habitats are waiting to be studied and undescribed species await collection. Collections (museums' and naturalists') are an important resource to provide more background material, but historical comparison of the number of species with the present day should not be used because inadequate background information will invariably mean that more species will be found today. Invertebrates are a very adaptive group and there could be large changes in species composition over time in response to environmental change.

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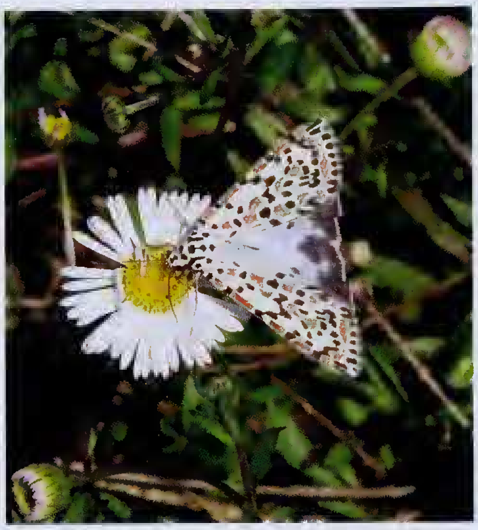

Above: (L) St Andrews Cross spider. Photo by Anne Morton; (R) Heliotrope moth. Photo by Virgil Hubregtse.
Below: Cricket. Photo by Anne Morton